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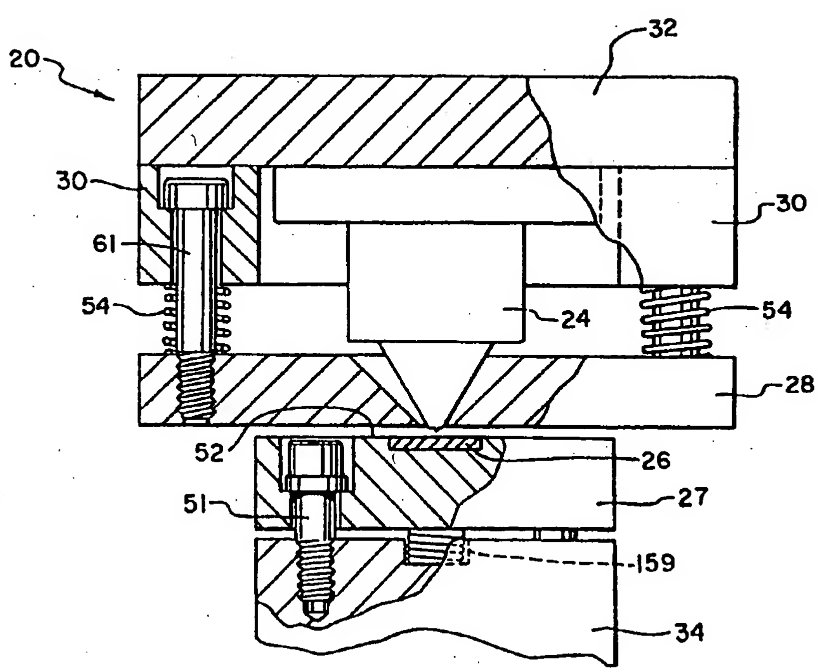

(57) Abstract

Apparatus and methods for simultaneous cutting and sealing the same cut edge of an open cell or porous edged sheeting or film in one step. The sheeting (22) may be pinch cut, shear cut, kiss cut, or die cut using various tool configurations.

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APPARATUS AND METHOD FOR CUTTING AND SEALING POROUS EDGED SHEETING

Field of the Invention

The invention relates to an apparatus and method of cutting and sealing a material. In particular, the invention relates to an apparatus and method of simultaneously cutting and sealing the same cut edge of a porous edged or open cell sheeting.

Background of the Invention

Currently, there are several methods used to cut and seal the same cut edges of porous or open celled materials, such as retroreflective tapes or sheetings. One method is to cut the sheeting or tape with a razor or similar sharp blade. After the edge is cut, a liquid sealer is brushed onto the sheeting or tape to seal the edges. This is a time consuming procedure and relies on the installer's skill to produce an acceptable seal. In addition, the sealer may contain solvents which are harmful to the environment.

Another method that has been used is a two step process during which the sheeting or tape is first heat sealed using heat and pressure. The sheeting is then cut through the seal in a separate step. Use of this method requires a wide seal and/or very accurate registration between the seal and the cut.

In addition, the sheeting or tape material may be sealed using an ultrasonic weld, and then cut in a separate step. In this method, the seal or seam produced is generally wider than necessary, so that the sheeting may be cut down the width of the seam easily. The sealed edge produced is often not uniform in width due to slitting inaccuracies. In addition, two steps are required.

It is known to pinch cut non-retroreflective sheetings and webs of both woven, non-woven and sheeted materials. These devices generally fuse two or more layers during the cutting process. United States Patent No. 5,110,399 (Yoshida et al.), United States Patent No. 4,863,544 (Plate et al.), United States Patent Nos. 3,257,256, and 3,384,528 (both Lehmacher et al.), and United States Patent No. 2,117,452 (Robinson et al.), are examples of patents which disclose pinch cutting the sheetings or tapes. U.S. Patent No. 5,110,399, relates to an apparatus used to heat bond thermoplastic resin sheeting using a heated blade and non-heated pressing members comprising a heat resistant material. U.S. Patent Nos. 3,257,256 and 3,384,528, relate to apparatus used to cut thermoplastic bags. The heated sealing flats are separate from the heated blade. U.S. Patent No. 2,117,452, discloses a machine used to cut and simultaneously unite a stock material. The stock material is heated by the anvil, without directly heating the seaming wheel or edge portions of the seaming wheel.

In addition, it is also known to cut and fuse single layers of woven polymer fabric to prevent fraying, such as disclosed in United States Patent No. 4,352,703 (Perron). This patent discloses an embosser comprising heated knives and heated embossing members, the embossing members being separate from the knives. Various methods of cutting and fusing sheeting use a heated wire and various types of clamps, as shown, for example, in United States Patent No. 2,961,031 (Fener).

Retroreflective sheeting is used in many pedestrian, conspicuity and traffic channelization applications. Retroreflective sheeting, such as 3M SCOTCHLITE Brand Diamond Grade sheeting No. 980, often has air spaces which contribute to the reflectivity characteristics of the reflective sheeting. If the air spaces are not properly sealed when the sheeting is cut

or after the cut is made, the air spaces may fill with moisture and/or particulates. The desired reflectivity of the retroreflective sheeting is altered and the appearance is jeopardized when moisture or particulates contaminate the air spaces in the sheeting.

The National Highway Traffic Safety Administration issued a conspicuity rule requiring trailers built on or after December 1, 1993, to be equipped with retroreflective sheeting or reflex reflectors. This rule was published in the Federal Register, Vol. 57, No. 238, Dec. 10, 1992, pages 58406-58413. The rule applies to new trailers with an overall width of 80 inches or more and a gross vehicular weight rated (gvwr) of more than 10,000 pounds. The rule applies to vehicles such as pole trailers, tankers, automobile transporters, container chassis, garbage haulers, side loading beverage trailers, boat trailers, and other specialty equipment. It is possible that the rule will also be extended to railway cars. The basic requirement of the conspicuity rule requires that reflective sheeting be applied in a pattern of alternating white and red color segments to the side and rear of the trailer, and in white only to the upper rear corners of the trailer. The rule requires that the reflective sheeting be in widths of 50 mm, 75 mm, or 100 mm (approximately 2, 3, and 4 inches) and lengths of approximately 500 mm (roughly one and a half feet) plus or minus about 152 mm (6 inches). Dispensers or applicators may be used to apply the retroreflective sheeting. The sheeting pieces positioned on these vehicles are very susceptible to moisture, particulate, and other types of roadway contamination because of the harsh environment under which the vehicles operate. As a result, the cut sheeting pieces to be applied to the vehicles must be effectively sealed to preserve the reflectivity and th appearance of the retroreflective

sheeting. Numerous pieces of retroreflective sheeting will need to be applied to the vehicles, which will require a convenient method of cutting and sealing the pieces of sheeting.

Summary of the Invention

The invention relates to an apparatus for simultaneous cutting and sealing of an edge of a porous edged sheeting. The apparatus includes a cutting blade for cutting the sheeting. The apparatus also comprises at least one sealing flat preferably made integral with the cutting blade, which has a sealing surface for compressing and sealing the cut sheeting, the sealing flat preferably having a surface with a width between about 0.254 millimeters (mm) and about 0.76 mm. Heating means arranged in thermal transfer relation to the at least one sealing flat for heating the sealing flat to aid in the sealing of the sheeting is also included in the apparatus. The apparatus also includes an anvil for positioning the sheeting proximate the cutting blade and the at least one sealing flat, so that the cut edge of the sheeting is simultaneously cut and sealed to preserve the reflectivity of the sheeting and to prevent contamination of the sheeting.

The invention also relates to an alternative apparatus for cutting and sealing the porous edge of a sheeting. The apparatus has a first cutting blade and second cutting blade for shearing the sheeting. The apparatus also comprises a first anvil for positioning of the sheeting against the first cutting blade. The apparatus also includes at least one sealing flat integral with the first and second cutting blades and the first anvil for sealing a cut edge of the sheeting. The apparatus also includes heating means for heating the at least one sealing flat, so that the cut edge of the sheeting is substantially simultaneously cut and

sealed to preserve the reflectivity of the sheeting and to prevent contamination of the sheeting.

In addition, the invention also relates to a method for cutting, such as by pinch, die, and kiss cutting, and sealing a porous edged sheeting. An anvil and an opposing cutting and sealing tool are provided. The cutting and sealing tool is heated. A sheeting having a thickness is positioned on the anvil. The anvil and the cutting and sealing tool are moved relative to each other until the sheeting comes in contact with the cutting and sealing tool. The sheeting is cut by pressing the cutting and sealing tool into the sheeting to a predetermined depth. The sheeting is simultaneously sealed and compressed between the cutting and sealing tool and the anvil.

Further, the invention relates to a method for shear cutting and sealing porous edge sheeting. A first assembly having a first cutting surface, a first anvil, and a plurality of sealing surfaces, and a second assembly having a second cutting surface are provided. The first assembly is heated. The sheeting is positioned on the second assembly. The cutting edges are moved relative to each other to completely shear and cut the sheeting. The sheeting is simultaneously sealed and compressed between the first assembly and the second assembly.

Brief Description of the Drawings

Figure 1 is a fragmentary view of the apparatus used to cut and seal the same cut edge of a porous edged or open cell sheeting.

Figure 2 is a simplified sectional view of the die, anvil and sheeting material.

Figure 3 is a simplified sectional view of the die in contact with the anvil and sheeting material.

Figure 4 is an enlarged fragmentary sectional view of the cutting edge of the die cutting through the liner of the sheeting material.

Figure 5 is an enlarged fragmentary sectional view of the cutting edge of the die meeting but not cutting the liner of the sheeting material.

Figure 6 is a partial front elevational view of the tool showing stops.

Figure 7 is a top plan view of a die cut retroreflective material assembly.

Figure 8 is a simplified sectional view of an alternative embodiment of a tool used to die cut sheeting.

Figure 9 is a simplified sectional view of an alternative embodiment of a tool used to die cut porous edged sheeting.

Figure 10 is a simplified sectional view of an alternative embodiment of a tool used to die cut porous edged sheeting.

Figure 11 is simplified mechanical diagram of an alternative embodiment rotary die and anvil.

Figure 12 is a simplified mechanical diagram of an alternative embodiment of a rotary die and anvil.

Figure 13 is a cross section schematic view of the sealed porous edged retroreflective sheeting.

Figure 14 is a cross section schematic view of sealed kiss cut or die cut retroreflective sheeting.

Figure 15 is a simplified side view of an alternative embodiment of a die and anvil.

Figure 16 is a view in operation of the die and anvil of Figure 15.

Figure 17 is a simplified elevation view of an alternative embodiment rotary die and anvil.

Figure 18 is a simplified sectional view of an apparatus in an open position for shear cutting porous edged sheeting.

Figure 19 is a simplified sectional view of an apparatus in a closed position for shear cutting porous edged sheeting.

Figure 20 is a fragmentary view of an apparatus in an open position for shear cutting porous edged sheeting.

Figure 21 is a fragmentary view of an apparatus in a closed position for shear cutting porous edged sheeting.

Figure 22 is a cross section schematic view of sealed shear cut porous edged retroreflective sheeting.

Detailed Description of the Invention

The invention relates to apparatus and methods for simultaneous cutting and sealing the same cut edge of an open cell or porous edged sheeting, such as retroreflective sheeting or film, in one step. The film or sheeting may be shear cut, die cut, pinch cut, butt cut, kiss cut, or through cut. Throughout this application, die cutting refers generally to cutting a form in an article either partially or completely through using at least one sharpened edge or blade and an anvil. The blade and anvil may be flat or cylindrical. Pinch cutting refers to completely severing an article by pinching the material between the sharpened edge and the anvil. Kiss cutting and butt cutting generally refer to partially cutting an article between the blade or sharpened edge and the anvil. Shear cutting generally refers to cutting an article by passing two sharpened edges past each other in close proximity, completely severing the article in the path between the two sharpened edges.

Figure 1 discloses a fragmentary view of a tool 20 for cutting and sealing the same cut edge of a porous edged or open cell film, tape or sh eting, such as a retroreflective sheeting. Generally, the sealing

and cutting tool 20 comprises punch or die 24, anvil 26, and stripper plate 28. Die 24, and dies used in the embodiments described below, are securely mounted to a guide plate 30 of a mounting plate 32. Anvil 26, and the anvils described in the embodiments described below, are positioned at, and preferably secured to, anvil holder 27. Anvil holder 27 is positioned against anvil carrier 34 by stripper bolts 51 and is spring loaded away from anvil carrier 34 by spring 159. Stripper plate 28 is suspended from mounting plate 32 and guide plate 30 by, for example, stripper bolts 61 and is resiliently biased away from guide plate 30 by resilient biasing means 54.

Referring to Figure 2, a simplified sectional view of tool 20 in an open position is illustrated. Die 24 is preferably used to pinch cut or kiss cut sheeting 22. Die 24 comprises a block 36, blade 38, heater 40, sealing flats 42, 44, and thermocouple 46. Block 36 preferably comprises a heat conducting material, such as steel, brass or copper. Block 36 may be of varying dimensions depending on the specific application. Heater 40 is preferably a cartridge heater, although other types of heaters may also be utilized. Heater 40 is preferably used to heat block 36, including sealing flats 42, 44 and blade 38. Thermocouple 46 is used to regulate the amount of heat being transferred to block 36 and provides temperature feedback to a heat source controller (not shown) which is operatively connected with heater 40.

Blade 38 is configured substantially within block 36, and is substantially rectangular in shape, although the shape may vary. For the disclosed application, as shown in Figure 4, the width W_1 of blade 38 is preferably in a range of widths from about 0.64 millimeters (mm) to about 2.54 mm, and more preferably about 1.4 mm. Blade 38 may comprise a variety of materials, such as carbide steel or high carbon steel.

Cutting edge 48 of blade 38 is preferably at an included angle α of about 60° to 120°, and more preferably about 90°, as shown in Figure 4 and Figure 5. As the angle increases, blade 38 is normally rendered stronger and less likely to deform. However, the increase is limited by the ability to cut, which happens better at lower angles. For use on typical sheetings, such as described below, cutting edge 48 preferably protrudes approximately 0.13 mm to 0.25 mm, more preferably 0.18 mm, from sealing flats 42, 44 toward anvil 26. Cutting edge 48 of blade 38 preferably extends substantially the entire length of block 36 so that blade 38 pinch cuts porous edged sheeting 22 across a substantial dimension. Blade 38 may include gap means on the cutting edge 48 to create perforations as sheeting 22 is cut and sealed. Sides 47a, 47b of cutting edge 48, as illustrated in Figure 4 and Figure 5, aid in the compression of sheeting during the cutting action of blade 38.

As shown in Figures 4 and 5, sealing flats 42, 44 are positioned at end 50 of block 36, and preferably intersect both sides 47a, 47b of cutting edge 48 of blade 38 to compress and seal film 22 during cutting action by the blade. Sealing flats 42, 44 are preferably integral with blade 38. For use on sheetings described below, the width W_2 of sealing flats 42, 44 to create a good seal leg on the cut edge of sheeting 22, best shown in Figure 4, preferably varies from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing flats 42, 44 are substantially planar, and also preferably extend the length of block 36.

Referring again to Figure 1, anvil 26 and anvil holder 27 are preferably movably positioned so that anvil 26 can be raised and lowered relative to die 24 to cut and seal sheeting 22. It is recognized that die 24 may be raised and lowered relative t anvil 26.

Anvil 26, positioned on anvil holder 27, and die 24 can be raised, lowered and mov d into different opened and closed orientations by, for example, pneumatic means, such as an air cylinder, springs, a motor, a crank, and the like. A portion of the upper surface 52 of anvil 26 and anvil holder 27, such as a movable plate, may be levelled upon contact of anvil 26 with blade 38, allowing parallel contact between anvil 26 and blade 38. Alternatively, blade 38 may be moved against anvil 26. Anvil 26 is made of a durable material, such as steel.

Figures 2 and 3 show sheeting 22 positioned on upper surface 52 of anvil 26. Generally, sheeting 22 includes a porous edged sheeting layer 55 and a release liner 56, best shown in Figure 4 and Figure 5. It is recognized that sheeting 22 may only comprise sheeting layer 55 without release liner 56, or it may even comprise additional layers. Sheeting 22 may comprise a porous edged sheeting or an open cell sheeting, film, or tape, such as a thermoplastic film, although other materials may be utilized. In addition, the methods and apparatus of the present invention are particularly applicable to laminated, pre-fused sheeting structures having a porous or open cell edge to be sealed. Sheeting 22 includes retroreflective sheeting material, such as 3M SCOTCHLITE Brand Diamond Grade reflective sheeting No. 980 and 3M SCOTCHLITE Brand High Intensity Grade reflective sheeting No. 790, both manufactured by Minnesota Mining and Manufacturing Company of Saint Paul, Minnesota. The stiffness or the flexibility of film or sheeting 22 may vary depending on the material, but the thickness is preferably between about 0.38 mm to about 0.89 mm, and more preferably about 0.64 mm, including liner 56.

Retroreflective directly machined cube corner articles are often designed to receive a sealing sheeting which is applied to the retroreflective

article in order to maintain a low refractive index material, such as air, next to the retroreflective elements for improved performance. In conventional arrays, this medium is often placed in direct contact with the cube corner elements in ways which degrade total light return.

Suitable materials for retroreflective articles or layers of sheeting 22 of this invention are preferably transparent materials which are dimensionally stable, durable, weatherable, and easily replicated into the desired configuration. Examples of suitable materials include glass; acrylics, which have an index of refraction of about 1.5, such as PLEXIGLAS Brand resin manufactured by Rohm and Haas Company; polycarbonates, which have an index of refraction of about 1.59; reactive materials such as taught in United States patents Nos. 4,576,850, 4,582,885 and 4,668, 558; polyethylene based ionomers, such as those marketed under the brand name of SURLYN by E.I. Dupont de Nemours and Co., Inc.; polyesters, polyurethanes; and cellulose acetate butyrates. Polycarbonates are particularly suitable because of their toughness and relatively higher refractive index, which generally contributes to improved retroreflective performance over a wider range of entrance angles. These materials may also include dyes, colorants, pigments, UV stabilizers, or other additives. Transparency of the materials ensures that the separation or truncated surfaces will transmit light through those portions of the article or sheeting.

Referring again to Figure 1, stripper plate 28 is positioned around blade 38 and sealing flats 42, 44. Resilient biasing means 54 and stripper plate 28 provide a clamping force on sheeting 22 so that the sheeting 22 does not move during the cutting and sealing process. Sheeting 22 first contacts stripper plate 28 as anvil 26 and anvil holder 27 are raised, as

discussed above. The stripper plate prevents the sheeting from sticking to di 24, and is preferably utilized when flexible types of sheeting 22 are used. When stiffer, less flexible sheetings 22 are used, then the stripper plate may be optional.

Figure 3 is a simplified sectional view of die 24 in contact with anvil 26 and sheeting 22. Anvil 26 is positioned adjacent sealing flats 42, 44, block 36, and blade 38. Sheeting 22 is positioned between sealing flats 42, 44, blade 38 and anvil 26. Blade 38 is forced through sheeting 22 as anvil 26 is raised, pinching and completely cutting sheeting 22 as cutting edge 48 contacts anvil 26. Alternatively, if blade 38 is stopped by other means before contacting anvil 26, sheeting 22 is only partially cut, as shown in Figure 5.

Figure 4 and Figure 5 are each enlarged fragmentary sectional views of blade 38 cutting sheeting 22. In Figure 4, cutting edge 48 of blade 38 has cut completely through sheeting layer 55 and liner 56, the full thickness of sheeting 22. Alternatively, as shown in Figure 5, blade 38 may be used to kiss cut or butt cut sheeting 22 by only cutting partially through sheeting 22, stopping after only a slight entry into liner 56. In another embodiment, blade 38 may also be stopped before entry into liner 56. In these embodiments, the cut edges of sheeting 22 are preferably compressed to a height of about 0.13 mm to 0.25 mm, and more preferably about 0.18 mm, between sealing flats 42, 44, sides 47a, 47b of cutting edge 48, and anvil 26.

Referring to Figure 6, a partial front elevational view of tool 20 including stops 58 is shown. Stops 58 may be used on tool 20 to limit cutting depth so as to prevent cutting through liner 56 of sheeting 22. In that case, stops 58 create a gap of a dimension D, as shown in Figur 6, so that tool 20

does not cut through liner 56. Stops 58 preferably extend from mounting plate 32 at stop end 57, and are positioned to abut against the upper surface 52 of anvil holder 27 at stop end 59. The height of stops 58 is preferably adjustable relative to blade 38 and sealing flats 42, 44, to achieve the desired cutting depth and the desired seal, i.e., so that sheeting layer 55 is completely cut through, and liner 56 is not cut, or is just slightly cut, as shown in Figure 5. In this embodiment, stops 58 define the gap between sealing flats 42, 44 and anvil 26, thereby determining the amount or distance sheeting 22 is compressed. Stops 58 extend below cutting edge 48 of blade 38 when sheeting 22 is kiss cut or butt cut, as shown in Figure 5. Preferably, stops 58 are mechanical stops, such as screws, posts, shims or other suitable means. Alternatively, spring pressure from the springs between anvil 26 and anvil holder 27 may be used to regulate the force applied to sheeting 22 and thus the depth of cut. The spring pressure may also vary depending on the width and composition of sheeting 22. In addition, adjusting the stroke of an air cylinder (not shown), as discussed above, connected to anvil carrier 34 may be used to stop anvil 26 at a selected distance from die 24, or stop die 24 at a selected distance from anvil 26, so that cutting edge 48 of blade 38 does not completely penetrate and sever liner 56.

In operation of the preferred embodiment, a power cylinder (not shown), such as an air cylinder, is activated to raise anvil 26 toward die 24. Block 36, blade 38, and sealing flats 42, 44 are heated by heater 40 in block 36. Sheeting 22 is positioned on upper surface 52 of anvil 26 and anvil holder 27. As anvil 26 is raised, cutting edge 48 of heated blade 38 is forced through sheeting 22, in a pinch cutting motion. Simultaneous with the cutting, sealing flats 42, 44 on heated block 36 melt, compress and seal the porous edge

or open cells of sheeting 22 on both sides of blade 38 between sealing flats 42, 44, sides 47a, 47b of cutting edge 48 and anvil 26. The edge of the cut piece of sheeting 22 and the sheeting from which it has been cut are sealed simultaneously.

Sheetings 22, such as retroreflective sheeting 22, may also be die-cut using this invention. A die-cut retroreflective material assembly preferably includes a laminated structure having at least one sheet of retroreflective material of a predetermined configuration having at least one surface coated with a pressure sensitive adhesive. The pressure sensitive adhesive is preferably permanently adhered to the retroreflective material. It is recognized, however, that the adhesive need not be permanently applied to the retroreflective material, and that the retroreflective material may not include an adhesive layer. This combination of retroreflective material and adhesive is releasably adhered to a liner, with the release liner being applied to the adhesive side of the retroreflective material. Such die-cut retroreflective material assemblies are typically used in processes or applications in which the demarcation zone is not a single straight line, but is curved, continuous, closed, or otherwise unusually configured. The retroreflective sheeting may comprise only a single sheet of retroreflective material on a sheet of liner material, or it may comprise a plurality of sheets of retroreflective material adhered along an elongate sheet of liner material that may be wound around a hub of a reel from which the sheets of retroreflective material are sequentially removed.

Referring to Figure 7, a top view of an exemplary embodiment of a die-cut retroreflective sheeting 22 is shown. Generally, sheeting 22 includes a release liner 56, a continuous sheet of a retroreflective material sheeting layer 55 having a

design periphery 67 of a predetermined shape, and a layer 69 of a pressure sensitive adhesive permanently adhered on one side of the retroreflective material sheeting layer 55. Layer 69 of pressure sensitive adhesive is releasably adhered to the release liner 56.

In operation, a rotary die, or other device, such as a remotely or robotically operated wheel, or a reciprocating die used in a press and operated as discussed above in reference to Figures 1-6, can be used to cut and seal around the design periphery 67 through the sheet of retroreflective material sheeting layer 55 and adhesive layer 69, but not through release liner 56. Scrim 71, the excess retroreflective material sheeting layer 55 outside design periphery 67 of the retroreflective article may be removed after the die cutting, leaving design periphery 67 releasably adhered to release liner 56 at multiple positions on liner 56. Alternatively, the rotary die, or other device, may cut all the way through release liner 56, so that design periphery 67 is releasably adhered to liner 56 having the same shape as design periphery 67, and discarding scrim 71 and excess liner 56 of the roll stock.

Figure 8 is a simplified sectional view of an alternate embodiment of a tool 20' which may be used to die cut sheeting 22. Tool 20' comprises die 24a and anvil 26a. Die 24a preferably comprises a heat conducting material, such as brass, steel, or copper. Die 24a preferably comprises a cutting edge 48a, a sealing flat 43, a block, a heater, and a thermocouple, as discussed above with reference to die 24 so that die 24a is heated. Alternatively, die 24a may comprise cutting edge 48a and sealing flat 43, with the block including the heater and the thermocouple being a separate component. The block preferably comprises a heat conducting material, such as steel, brass or copper. The block may be of varying dimensions,

depending on the specific application. The heater is preferably a cartridge heater, although other types of heaters may also be utilized. The heater is preferably used to heat the block, including sealing flat 43 and cutting edge 48a. The thermocouple is used to regulate the amount of heat being transferred to the block and provides temperature feedback to a heat source controller (not shown) which is operatively connected with the heater.

Die 24a may be configured substantially within the block or may be separate from the block. Die 24a may vary in shape depending on the size and configuration of piece part 63. For the disclosed application, the width W_3 of die 24a varies in shape depending on the size and configuration of piece part 63. Die 24a may comprise a variety of materials, such as carbide steel or high carbon steel. Cutting edge 48a of die 24a is preferably at an included angle α of about 30° to 60°, more preferably 45°, as shown in Figure 8, such that the side 47c of cutting edge 48a is substantially planar or flat, producing a crisper, more defined cut edge on piece part 63. For use on typical sheetings, such as described above, cutting edge 48a preferably protrudes approximately 0.13 mm to 0.25 mm, more preferably 0.18 mm, from sealing flat 43 toward anvil 26a. The distance cutting edge 48a protrudes beyond sealing flat 43 may vary, however depending, for instance, on whether liner 56 will be cut through. As shown in Figure 8, cutting edge 48a does not extend into liner 56. Cutting edge 48a of die 24a preferably extends substantially the entire length of the block so that die 24a die cuts porous edged sheeting 22 across a substantial dimension. Die 24a may include gap means on the cutting edge 48a to create perforations as sheeting 22 is cut and sealed. Side 47c of cutting edge 48a, as illustrated in Figure 8,

aids in the compression and containment of sheeting during the cutting action of die 24a.

As shown in Figure 8, sealing flat 43 is positioned at end 61 of tool 20', and preferably intersects side 47c of cutting edge 48a to compress and seal film 22 during cutting action by the die. Sealing flat 43 is preferably integral with cutting edge 48a. For the materials described above, the width of sealing flat 43 to create a good seal leg on the cut edge of sheeting 22 preferably varies from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing flat 43 is substantially planar, and also preferably extends the length of the block. The cut edge of piece part 63 is preferably compressed to a height H of about 0.13 mm to 0.25 mm, more preferably about 0.18 mm, between sealing flat 43, side 47c of die 24a, and anvil 26a, as shown in Figure 14.

Anvil 26a is preferably movably positioned on an anvil holder so that anvil 26a can be raised and lowered relative to die 24a to cut and seal sheeting 22, as discussed above with reference to Figure 1. It is recognized that die 24a may be raised and lowered relative to anvil 26a. Anvil 26a, positioned on the anvil holder, and die 24a can be raised, lowered and moved into different opened and closed orientations by, for example, pneumatic means, such as an air cylinder, springs, a motor, a crank, and the like. Anvil 26a is made of a durable material, such as steel.

As shown in Figure 8, die 24a is in a closed orientation with respect to anvil 26a. Anvil 26a is positioned adjacent sealing flat 43, cutting edge 48a, and die 24a. Sheeting 22 is positioned between sealing flat 43, die 24a, and anvil 26a. Die 24a cuts through sheeting layer 55 as anvil 26a is raised, cutting sheeting layer 55 as cutting edge 48a contacts sheeting 22. Tool 20' can be used to simultaneously die cut and

seal around a desired design periphery to produce piece part 63, such as a retroreflective piece part, in sheeting layer 55 of sheeting 22, but not cut through release liner 56. Scrim, the excess material outside the design periphery of piece part 63, may be removed after the die cutting, leaving piece part 63 releasably adhered to release liner 56 at multiple positions on liner 56. Generally, preferably only the cut edge of the design periphery of piece part 63 is sealed using the embodiment shown in Fig. 8. The cut edge of the scrim material is generally not sealed. Alternatively, tool 20' may cut all the way through release liner 56, so that the design periphery which has been die cut is releasably adhered to liner 56 having the same shape as the design periphery, and discarding the scrim and excess liner 56 of the roll stock. Again, in this embodiment, preferably only the cut edge of the design periphery of piece part 63 is sealed.

Figures 9 and 10 are simplified sectional views of an alternate embodiment of a tool 20" which may be used to die cut sheeting 22. Tool 20" comprises die 24b and anvil 26b. Die 24b preferably comprises a heat conducting material, such as brass, steel, or copper. Die 24b comprises a blade 38b, sealing flats 42b, 44b, a block, a heater, and a thermocouple, as discussed generally above with reference to die 24 so that die 24b is heated. Alternatively, die 24b may comprise cutting edge 48b and sealing flats 42b, 44b, with the block including the heater and the thermocouple being a separate component. The block preferably comprises a heat conducting material, such as steel, brass or copper. The block may be of varying dimensions, depending on the specific application. The heater is preferably a cartridge heater, although other types of heaters may also be utilized. The heater is preferably used to heat the block, including sealing flats 42b, 44b and

blade 38b. The thermocouple is used to regulate the amount of heat being transferred to the block and provides temperature feedback to a heat source controller (not shown) which is operatively connected with the heater.

Blade 38b is configured substantially within the block, and may vary in shape depending on the size and configuration of the piece part. For the disclosed application, the width W_4 of die 24b varies depending on the size and configuration of the piece part. Die 24b and blade 38b may comprise a variety of materials, such as carbide steel or high carbon steel. Cutting edge 48b of blade 38b is preferably at an included angle α of about 60° to 120°, and more preferably about 90°, as shown in Figure 9 and Figure 10. As angle α increases, blade 38b is normally rendered stronger and less likely to deform. However, the increase is limited by the ability to cut, which happens better at lower angles. For the materials noted above, cutting edge 48b preferably protrudes approximately 0.13 mm to 0.25 mm, more preferably 0.18 mm, from sealing flats 42b, 44b toward anvil 26b. The distance cutting edge 48b protrudes beyond sealing flats 42b, 44b may vary, however, depending, for instance, on whether liner 56 will be cut through. As shown in Figure 9, cutting edge 48b does not extend into liner 56, so that liner 56 is not cut. Stops may be used to determine the depth to which sheeting 22 is cut. Cutting edge 48b in Figure 10 does extend and cut through liner 56. Cutting edge 48b of blade 38b preferably extends substantially the entire length of the block so that blade 38b die cuts porous edged sheeting 22 across a substantial dimension. Blade 38b may include gap means on the cutting edge 48b to create perforations as sheeting 22 is cut and sealed. Sides 47d, 47e of blade 38b, as illustrated in Figures 9 and 10, aid in the

compression of sheeting during the cutting action of blade 38b.

As shown in Figures 9 and 10, sealing flats 42b, 44b are positioned at end 65 of die 20", and preferably intersects sides 47d, 47e of blade 38b to compress and seal film 22 during die cutting action by the blade. Sealing flats 42b, 44b are integral with blade 38b. For the materials described above, the width of sealing flats 42b, 44b to create a good seal leg on the cut edge of sheeting 22 preferably varies from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing flats 42b, 44b are substantially planar, and also preferably extend the length of the block. The cut edges of sheeting 22 are preferably compressed to a height H of about 0.13 mm to 0.25 mm, more preferably about 0.18 mm, between sealing flats 42b, 44b, the sides 47d, 47e of blade 38b, and anvil 26b, as shown in Figure 14.

Anvil 26b is preferably movably positioned on an anvil holder so that anvil 26b can be raised and lowered relative to die 24b to cut and seal sheeting 22, as discussed above with reference to Figure 1. It is recognized that die 24b may be raised and lowered relative to anvil 26b. Anvil 26b, positioned on the anvil holder, and die 24b can be raised, lowered and moved into different opened and closed orientations by, for example, pneumatic means, such as an air cylinder, springs, a motor, a crank, and the like. Anvil 26b is made of a durable material, such as steel.

As shown in Figure 9 and Figure 10, die 24b is in a closed orientation with respect to anvil 26b. Anvil 26b is positioned adjacent sealing flats 42b, 44b, die 24b, and blade 38b. Sheeting 22 is positioned between sealing flats 42b, 44b, blade 38b and anvil 26b. Blade 38b cuts through sheeting layer 55 as anvil 26b is raised, cutting she ting layer 55 as cutting edge 48b contacts sheeting 22. As shown in Figure 9,

tool 20'' may preferably be used to simultaneously die cut and seal around a desired design periphery to produce piece part 63 in sheeting layer 55 of sheeting 22, while not cutting through release liner 56. Stops may be used on tool 20" to limit cutting depth so as to prevent cutting through liner 56 of sheeting 22. Scrim, the excess material outside the design periphery of piece part 63, may be removed after the die cutting, leaving piece part 63 releasably adhered to release liner 56 at multiple positions on liner 56. The cut edge of the design periphery of article 63 and the cut edge of the scrim material are generally sealed. Alternatively, tool 20'' may cut all the way through release liner 56, as shown in Figure 10, so that the design periphery which has been die cut is releasably adhered to liner 56 having the same shape as the design periphery, and discarding the scrim and excess liner 56 of the roll stock. Again, in this embodiment, the cut edge of the design periphery of piece part 63 and the cut edge of the scrim material are sealed.

Referring to Figure 11, a simplified mechanical diagram of a rotary version of tool 20 in Figures 1-5 is shown. Tool 60 comprises rotary die 100 and anvil 102. Die 100 preferably comprises a heat conducting material, such as steel, brass or copper. Die 100 including blade 104 is preferably heated by a heater, preferably a cartridge heater, although other types of heaters may also be utilized. A thermocouple is used to regulate the amount of heat being transferred to die 100 and provides temperature feedback to a heat source controller (not shown) which is operatively connected with the heater. Die 100 may be of varying dimensions. Die 100 rotates on axle 106, to continuously present a cutting edge 108 on sheeting 22, with the die cutting edge 108 being substantially circular when viewed axially. Die 100 rotates either

by friction of the cutting and sealing action, or it may be rotated by some external means. Sheeting guiding flanges may be used to guide sheeting 22. A plurality of tools 60 may be positioned at multiple locations across a web of sheeting 22 to cut a sheet into plural strips at the same time.

Blade 104 is configured substantially within die 100, and is substantially rectangular in shape, although the shape may vary. Referring to Figures 4 and 11, the width W_1 of blade 104 is preferably in a range of widths from about 0.64 millimeters (mm) to about 2.54 mm, and more preferably about 1.4 mm. Blade 104 may comprise a variety of materials, such as carbide steel or high carbon steel. Cutting edge 108 of blade 104 preferably extends substantially the entire circumference of die 100 so that blade 104 cuts porous edged sheeting 22 across a substantial dimension. Cutting edge 108 of blade 104 preferably comprises an included angle α of about 60° to 120°, and more preferably about 90°. As angle α increases, blade 104 is rendered stronger and less likely to deform. However, the increase is limited by the ability to cut which happens better at lower angles. Cutting edge 108 preferably protrudes approximately 0.13 mm to 0.25 mm, more preferably 0.18 mm, from sealing flats 110, 112 toward anvil 102. The relative distance between cutting edge 108 and anvil 102 may be regulated, such as by stops 58 shown in Figure 6, so that tool 60 does not cut through liner 56. Blade 104 may include gap means on cutting edge 108 to create perforations as sheeting 22 is cut and sealed. Sides 114, 116 of cutting edge 108, as illustrated in Figure 11, aid in the compression of sheeting during the cutting action of blade 104. Blade 108 can be used to pinch cut, kiss or butt cut, and/or die cut porous or open cell edged sheeting 22.

Anvil 102 rotates on an axle 103. Anvil 102 is biased toward blade 104 and has means for levelling anvil 102 against blade 104, such as spring loading, resilient backing, and fixed or adjustable mounting. Alternatively, anvil 102 may be mounted at a predetermined position. Anvil 102 is made of a durable material, such as steel. Anvil 102 may be heated, but preferably has no heating capabilities.

Sealing flats 110, 112 flank blade 104 around the circumference of die 100 and are used to compress and seal sheeting 22 during cutting action by blade 104. Sealing flats 110, 112 are integral with blade 104. For use on sheetings described above, the width of sealing flats 110, 112 used to create a good seal leg on the cut edge of sheeting 22 may vary preferably from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing flats 110, 112 are substantially planar, and preferably extend around the circumference of die 100. Preferably, sealing flats 110, 112 are heated. The cut edges of sheeting 22 are preferably compressed to a height H of about 0.13 mm to 0.25 mm, more preferably about 0.18 mm, between sealing flats 110, 112, the sides 114, 116 of cutting edge 108, and anvil 102, as shown in Figure 13 and Figure 14.

In operation, sheeting 22 is fed into the interface between anvil 102 and die 100. Sheeting 22 is cut between blade 104 and anvil 102. The cut edges of sheeting 22 are simultaneously sealed between sealing flats 110, 112, sides 114, 116 of cutting edge 108, and anvil 102 using selected heat and pressure profiles, as described below.

Referring to Figure 12, a simplified mechanical diagram of an alternate rotary version of tool 60 in Figure 8 is shown. Tool 60' comprises rotary die 100a and anvil 102a. Die 100a preferably comprises a heat conducting material, such as steel,

brass or copper. Die 100a, including blades 104a, 105, is preferably heated by a heater, preferably a cartridge heater, although other types of heaters may also be utilized. A thermocouple is used to regulate the amount of heat being transferred to die 100a and provides temperature feedback to a heat source controller (not shown) which is operatively connected with the heater. Die 100a may be of varying dimensions. Die 100a rotates about an axis 107, to continuously present cutting edges 108a, 109 on sheeting 22, with the die cutting edges being substantially circular when viewed axially and radially, respectively. Die 100a rotates either by friction of the cutting and sealing action, or it may be rotated by some external means. Sheeting guiding flanges may be used to guide sheeting 22. A plurality of tools 60' may be positioned at multiple locations across a web of sheeting 22 to cut a sheet into plural strips at the same time.

Blades 104a, 105 are configured substantially within die 100a, and may be substantially rectangular in shape as shown in Fig. 12, although the shape may vary. For the disclosed application, the width of blades 104a, 105 is preferably in a range of widths from about 0.64 millimeters (mm) to about 2.54 mm, and more preferably about 1.4 mm, as discussed in relation to Figures 4 and 11. Blades 104a, 105 may comprise a variety of materials, such as carbide steel or high carbon steel. Cutting edges 108a, 109 of blades 104a, 105 are preferably at an included angle of about 60° to 120°, and more preferably about 90°. As angle α increases, blades 104a, 105 are normally rendered stronger and less likely to deform. However, the increase is limited by the ability to cut, which happens better at lower angles. Cutting edges 108a, 109 preferably protrude approximately 0.13 mm to 0.25 mm, more preferably about 0.18 mm, from sealing flats

110a, 112a, 113, 115, respectively, toward anvil 102a. Cutting edges 108a, 109 of blades 104a, 105 preferably extend substantially the entire length and width of die 100a so that blades 104a, 105 cuts porous edged sheeting 22 across a substantial dimension. Blades 104a, 105 may include gap means on cutting edges 108a, 109 to create perforations as sheeting 22 is cut and sealed. Sides 114a, 116a, 117, 119 of cutting edges 108a, 109 aid in the compression of the sheeting during the cutting action of blades 104a, 105. The relative distance between cutting edge 108a, 109 and anvil 102a may be regulated, such as by stops, so that tool 60' does not cut through liner 56. Tool 60' can be used to pinch cut, kiss cut, and/or die cut porous edged sheeting 22.

Anvil 102a may rotate about an axis 118. Anvil 102a is biased toward blades 104a, 105 and has means for levelling anvil 102a against blades 104a, 105, such as spring loading, resilient backing, and fixed or adjustable mounting. Alternatively, anvil 102a may be mounted at a predetermined position. Anvil 102a is made of a durable material, such as steel. Anvil 102a may be heated, but preferably has no heating capabilities.

Sealing flats 110a, 112a, 113, 115 are integral with blades 104a, 105, and are used to compress and seal sheeting 22 during cutting action by blades 104a, 105. For use on sheetings described above, the width of sealing flats 110a, 112a, 113, 115 used to create a good seal leg on the cut edge of sheeting 22 may vary preferably from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing flats 110a, 112a, 113, 115 are substantially planar, and preferably extend around the circumference and length of die 100a. Preferably, sealing flats 110a, 112a, 113, 115 are heated.

In operation, sheeting 22 is fed into the interface between anvil 102a and die 100a. Feeding means, such as a one way or single revolution clutch, may be utilized to feed the sheeting between die 100a and anvil 102a at a correct time, or sheeting 22 may be continuously fed between die 100a and anvil 102a. Sheeting 22 is cut between blades 104a, 105 and anvil 102a, such that four edges of sheeting 22 are simultaneously cut and sealed. The cut edges of sheeting 22 are simultaneously sealed between sealing flats 110a, 112a, 113, 115, sides 114a, 116a, 117, 119 of cutting edges 108a, 109, and anvil 102a using selected heat and pressure profiles, as described below. Sheeting 22 is preferably compressed to a height H of about 0.13 mm to about 0.25 mm, more preferably about 0.18 mm, between sealing flats 110a, 112a, 113, 115 and anvil 102a where sheeting 22 has been die cut, as shown in Figure 13 and Figure 14.

Tool 60' can be used to simultaneously die cut and seal around a desired design periphery to produce a sealed, porous edged piece part or article in the sheeting, while not cutting through the release liner. Scrim may be removed after the die cutting, leaving the piece part or article releasably adhered to the release liner at multiple positions on the release liner. The cut edge of the design periphery of the piece part or article and the cut edge of the scrim material are generally sealed. Alternatively, tool 60' may cut all the way through release liner, similar to Figure 10, so that the design periphery which has been die cut is releasably adhered to the release liner having the same shape as the design periphery, and discarding the scrim and excess release liner of the roll stock. The cut edge of the design periphery of the piece part or article and the cut edge of the scrim material are generally sealed.

Referring to Figure 13, a cross section schematic view of a representative cut and sealed retroreflective sheeting 22 which has been pinch cut in accordance with the apparatus and methods illustrated in Figures 1-4 and Figures 10-12 is shown. Sheeting 22 comprises release liner 56, a pressure sensitive adhesive layer 41, a structural layer, such as a plastic resin layer 43, a retroreflective layer 45, and a plurality of air spaces 47 positioned between resin layer 43 and retroreflective layer 45. Edge 49 is at an angle of approximately 45°, which is determined by the non-included angle of blades 38, 108, 108a, 109. The simultaneous cutting and sealing process of the present invention produces a sealed area 53 in which air spaces 47 are eliminated. Sheeting 22 is preferably compressed to a height H of about 0.13 mm to 0.25 mm, more preferably 0.18 mm. In sealed area 53, retroreflective layer 45 is welded to resin layer 43. This further prevents moisture or particulates from entering the remaining air interface shown by spaces 47.

Figure 14 illustrates a cross section view of a representative cut and sealed retroreflective sheeting 22 using a kiss cut or butt cut method in which liner 56 has not been cut, as in Figures 5-6 and Figures 11-12, or using the die cut method discussed regarding Figures 7, 9 and 18-19. Sheeting 22 comprises release liner 56, adhesive layer 41, plastic resin layer 43, retroreflective layer 45, and an air interface area shown as a plurality of air spaces 47. The shape of blades 38, 38b, 108, 108a, 109 and cutting edge 48a can be seen as edges 49a, 49b in layers 41, 43, and 45 making up sheeting layer 55, extending up to, into or through adhesive layer 41, and not cutting through liner 56. Sheeting 22 is preferably compressed to a height H of about 0.13 mm to 0.25 mm, more preferably about 0.18 mm. Sealed areas 53a, 53b are

positioned on either side of cut edges 49a, 49b. Air spaces 47 have been eliminated in the sealed areas 53a, 53b. In sealed areas 53a, 53b, retroreflectiv layer 45 is welded or heat sealed to resin layer 43.

Figure 15 is a simplified side view of an alternative embodiment of tool 20. Tool 64 comprises a plurality of at least two-piece opposing assemblies 66, 68, comprising blades 70, 72, and anvils 74, 76. Assembly 66 is mounted to a guide plate 30 provided on a mounting plate 32, such as described in relation to Figure 1. Blades 70, 72 may be substantially identical in shape, and preferably the tops of blades 70, 72 are bevelled. Blades 70, 72 preferably comprise a durable material, such as carbide steel. Cutting edges 78, 80 of blades 70, 72 are preferably at an angle of about 90°. Preferably, cutting edges 78, 80 are mounted at selected angles relative to the other so as to reduce the width of sheeting 22 being cut at any given time. As a result, sheeting 22 is not shear cut through the entire width of sheeting 22, but is only cut along the angle where cutting edges 78, 80 come in contact and intersect, thereby reducing the amount of force necessary to shear sheeting 22. Cutting edges 78, 80 may include gap means on the cutting edges 78, 80 to create perforations as sheeting 22 is cut and sealed. Blades 70, 72 are preferably used to shear cut porous edged sheeting 22.

A heater, preferably a cartridge heater, is used to heat blade 70, although other types of heaters may also be utilized. Blade 72 may be heated, but is preferably not heated. A thermocouple is used to regulate the amount of heat being transferred to blade 70 and provide temperature feedback to a controller (not shown) which is operatively connected to the heater.

Sealing flats 82, 84, 86, 88 are used to compress and seal sheeting 22 and comprise mating

surfaces of blades 70, 72 and anvils 74, 76. Sealing flats 82, 86 are integral with blades 70, 72. The distance from cutting edge 78 to sealing surface 84 and the distance from cutting edge 80 to sealing surface 88 is substantially identical and is preferably greater than the thickness of sheeting 22 being cut and sealed. For the sheetings described above, the width of sealing flats 82, 84 to create a good seal leg on the cut edge of sheeting 22 may vary preferably from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. The width of sealing flats 86, 88 preferably varies from at least 0.254 mm to about 1.2 mm, and may be wider, as illustrated in Figure 15. Sealing flats 82, 84, 86, 88 are substantially planar, and preferably extend the length of blades 70, 72 and anvils 74, 76.

Anvil 74 is attached to blade 70 by suitable means. Anvil 76 is attached to blade 72 by suitable means. Preferably, assembly 68 is mounted on anvil holder 27 and spring loaded to an anvil carrier 34, such as described above in relation to Figure 1. The force is preferably regulated and alignment achieved by spring pressure. Anvils 74, 76 are made of a durable material, such as carbide steel. Anvil 74 is preferably heated using a heater, such as a cartridge heater. Anvil 76 is preferably not heated. Assembly 66 comprising blade 70 and anvil 74 is preferably stationary, and assembly 68 comprising blade 72 and anvil 76 may be raised and lowered, as described above. However, it is recognized that assembly 68 could be stationary and assembly 66 could be positionable. Sheeting 22 is positioned between assembly 66 and assembly 68.

Referring to Figure 16, tool 64 is shown in operation in a closed position, with the cutting edge of assembly 66 in contact with the cutting edge of assembly 68. As assembly 68 is raised toward assembly

66, sheeting 22 is shear cut as cutting edge 78 on assembly 66 contacts cutting edg 80 on assembly 68, while heating, compressing, and sealing the porous or open cell cut edges of sheeting 22 between sealing flats 82, 88 and between sealing flats 84, 86 immediately after cutting. Sheeting 22 is completely cut through. Preferably, alignment means are included to ensure proper orientation of cutting edges 78, 80. The cut edges of sheeting 22 are preferably compressed to a height H of about 0.13 mm to about 0.25 mm, more preferably about 0.18 mm between sealing flats 82, 88 and between sealing flats 84, 86 where sheeting 22 has been shear cut, as shown in Figure 22.

Figure 17 illustrates a simplified elevation view of an alternative rotary embodiment of tool 64 in Figures 15 and 16. This embodiment is especially useful in “web direction” slitting or “transverse direction” cutting applications. Tool 64’ comprises rotary dies 70a, 72a and anvils 74a, 76a. Dies 70a, 72a are substantially circular when viewed axially. Dies 70a, 72a preferably comprise a durable material, such as carbide steel. Die 70a is preferably heated by a heater, preferably a cartridge heater, although other types of heaters may also be utilized. Die 72a is preferably not heated. A thermocouple is used to regulate the amount of heat being transferred to die 70a and provides temperature feedback to a controller (not shown) which is operatively connected to the heater. Dies 70a, 72a may be of varying dimensions. Die 70a rotates on axle 90, so as to continuously present a cutting surface 78a on sheeting 22. Die 72a preferably rotates on axle 92. Dies 70a, 72a rotate either by friction of the cutting and sealing action, or they may be rotated by some external means. Dies 70a, 72a preferably move in relation to sheeting 22, although this may be interchanged. Sheeting guiding flanges may be used to guide sheeting 22. A tool 64’

may be positioned at multiple locations across a web of sheeting 22 to cut a sheet into plural strips at the same time.

Die 70a has a cutting surface or edge 78a and a sealing surface 82a. Die 72a has a cutting surface or edge 80a and a sealing surface 86a. Cutting edges 78a, 80a are preferably at an angle of about 90°. Cutting edges 78a, 80a may include gap means on the cutting edges 78a, 80a to create perforations as sheeting 22 is cut and sealed. Cutting edge 78a is preferably heated, and cutting edge 80a is preferably not heated. Cutting edges 78a, 80a are preferably used to shear cut porous or open cell edged sheeting 22. Cutting edges 78a, 80a preferably extend beyond sealing surfaces 84a, 88a by a distance greater than the thickness of sheeting 22.

Anvil 74a rotates on axle 90, and is adjacent die 70a. Anvil 76a rotates on axle 92, and is adjacent die 72a. Anvil 74a is preferably heated by a heater, and anvil 76a is preferably not heated. Anvils 74a, 76a are preferably made of a durable material, such as carbide steel. Anvil 74a includes sealing surface 84a and anvil 76a includes sealing surface 88a.

Sealing surfaces 82a, 84a, 86a, 88a extend generally around the circumference of dies 70a, 72a, and anvils 74a, 76a. Sealing surfaces 82a,86a are preferably integral with cutting edges 78a, 80a. The width of sealing surfaces 82a, 84a, 86a, 88a to create a good seal leg on the cut edge of sheeting 22 may preferably vary in range from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing surfaces 82a, 84a, 86a, 88a are substantially planar. Sealing surfaces 82a, 84a, 86a, 88a are used to compress and seal sheeting 22 to a height H of preferably about 0.13 mm to about 0.25 mm, more preferably about 0.18 mm, as shown in Figure 22. One cut edge of sheeting 22 is compressed and sealed

between sealing surfaces 82a, 88a, and the other cut edge of sheeting 22 is compressed and sealed between sealing surfaces 84a, 86a.

In operation, sheeting 22 is fed into the interface between assembly 66 and assembly 68. Sheeting 22 is cut between cutting edges 78a, 80a and sequentially sealed by compressing sheeting 22 between sealing surfaces 82a, 84a, 86a, 88a immediately after the cutting of sheeting 22. Heated rotary dies are used to cut and seal sheeting 22 by slitting action and pinching material between a slitting knife or blade and a corresponding anvil.

Figures 18 and 19 are simplified sectional views of an alternate embodiment of an apparatus in an open and closed orientation which can be used to shear cut and seal sheeting 22. Apparatus 120 generally comprises a punch 122, anvil 124, and die 126. Sheeting 22 is positioned between an upper surface 128 of die 126 and punch 122.

As shown in Figure 18, punch 122 includes blade 130 which may be substantially identical in shape, and preferably the top of blade 130 is bevelled. Blade 130 preferably comprises a durable material, such as carbide steel. Cutting edge 134 of blade 130 is preferably at an angle of about 90°, although this may vary. Preferably, cutting edge 134 is mounted at selected angles to reduce the width of sheeting 22 being cut at any given time. As a result, sheeting 22 is not shear cut through the entire width of sheeting 22, but is only cut along the angle where cutting edge 134 intersects sheeting 22, thereby reducing the amount of force necessary to shear sheeting 22. Blade 130 is preferably used to shear cut porous edged or open cell sheeting 22.

A heater (not shown), preferably a cartridge heater, is positioned within punch 122 or within the block holding punch 122, and is used to heat blade 130.

Other types of heaters may also be utilized. A thermocouple may be used to regulate the amount of heat being transferred to blade 130 and provide temperature feedback to a controller (not shown) which is operatively connected to the heater.

Sealing flat 138 is used to seal and compress sheeting 22 and comprises mating surfaces of blade 130 and anvil 124. Sealing flat 138 is integral with blade 130. For the sheetings described above, the width of sealing flat 138 to create a good seal leg on the cut edge of sheeting 22 may vary preferably from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing flat 138 is substantially planar, and preferably extends the length of blade 130. Sealing flat 138 is used to compress and seal sheeting 22 against anvil 124.

Referring to Figure 18, die 126 includes cutting edge 142. Die 126 is attached to and positioned adjacent anvil 124. Preferably, die 126 and anvil 124 are mounted on anvil holder 27 and spring loaded to an anvil carrier 34, such as described above in relation to Figure 1. The force is preferably regulated and alignment achieved by spring pressure. Anvil 124 and die 126 are preferably made of a durable material, such as carbide steel. Anvil 124 and die 126 may be heated, but preferably are not heated. Punch 122 comprising blade 130 preferably may be raised and lowered, and the die/anvil assembly is preferably stationary. However, it is recognized that the die/anvil assembly could be positionable and punch 122 could be stationary.

Referring to Figure 19, apparatus 120 is shown in operation in a closed position, with cutting edge 134 of punch 122 in contact with the cutting edge 142 of die 126. As punch 122 is lowered toward anvil 124, sheeting 22 is shear cut as cutting edge 134 on punch 122 contacts cutting edge 142 on die 126, while

sequentially heating, compressing, and sealing the porous or open cell cut edges of sh eting 22 between sealing flat 138 and anvil 124 immediately after being cut. Sheeting 22 is completely cut through. Preferably, alignment means are included in apparatus 120 to ensure proper orientation of cutting edge 134 and cutting edge 142. The cut edges of sheeting 22 are preferably compressed to a height H of about 0.13 mm to about 0.25 mm, more preferably about 0.18 mm, between sealing flat 138 and anvil 124 where sheeting 22 has been shear cut, as shown in Figure 22.

Apparatus 120 can also be used to simultaneously die cut and seal around a desired design periphery to produce a porous edged article or piece part in the sheeting. The cut edge of the design periphery of the article or piece part 63 is generally sealed. It is recognized that the scrim could also be sealed by adding another sealing flat to punch 122. Preferably, apparatus 120 may cut all the way through release liner, so that the design periphery which has been die cut is releasably adhered to the release liner having the same shape as the design periphery, and discarding the scrim and excess release liner of the roll stock. It is recognized that the sheeting may only be partially cut.

Figures 20 and 21 are fragmentary views of an apparatus in an open and closed orientation, respectively, used to shear cut and seal sheeting 22. Apparatus 146 generally comprises punch 148, seal ring 150, and die 152. Punch 148 is securely mounted to a mounting plate 32, as discussed above in relation to Figure 1. Punch 148 may be of varying shapes, such as circular or square, depending on the desired end shape of the hole which is punched from sheeting 22. Punch 148 preferably comprises a durable material, such as carbide steel. Cutting edge 160 of punch 148 is preferably at an angle of about 90°, although this may

vary. Cutting edge 160 may include gap means on the cutting edge 160 to create p rforations as sheeting 22 is cut and sealed. Punch 148 is preferably used to shear cut porous edged or open cell sheeting 22.

Referring again to Figure 20, seal ring 150 is positioned around punch 148 and generally is the same approximate shape as punch 148. Seal ring 150 includes sealing flat 158 to seal and compress sheeting 22 against die 152. In one embodiment, seal ring 150 extends beyond cutting edge 160 of punch 148 when punch 148 is in an open, non-compressed orientation. Seal ring 150 may be suspended from mounting plate 32, such as by stripper bolts 154, and resiliently biased away from mounting plate 32 by resilient biasing means 156, such as a spring. Alternatively, seal ring 150 may be movably connected with punch 148. Resilient biasing means 156 and seal ring 150 provide a clamping force on sheeting 22 so that the sheeting 22 does not move during the cutting and sealing process. In a preferred embodiment, sheeting 22 first contacts seal ring 150 as die 152 is raised by means of anvil holder 27, as discussed above.

A heater, preferably a band heater, is positioned within seal ring 150 and is used to heat seal ring 150. Other types of heaters may also be utilized. A thermocouple may be used to regulate the amount of heat being transferred to seal ring 150 and provide temperature feedback to a controller (not shown) which is operatively connected to the heater.

Die 152 is positioned at, and preferably secured to, an anvil (not shown) which is secured to an anvil holder (not shown) and an anvil carrier (not shown), as discussed above in relation to Figure 1. Punch 148 is preferably stationary, and die 152 on anvil holder 27 and anvil carrier 34 may be raised and lowered, as described above. However, it is recognized

that die 152 could be stationary and punch 148 could be positionable.

Sealing flat 158 is used to compress sheeting 22 and comprises mating surfaces of seal ring 150 and die 152. For the sheetings described above, the width of sealing flat 158 to create a good seal leg on the cut edge of sheeting 22 may vary preferably from about 0.254 mm to about 1.2 mm, more preferably from about 0.55 mm to about 0.76 mm. Sealing flat 158 is substantially planar, and preferably extends around the circumference of seal ring 150. Sealing flat 158 is used to compress and seal sheeting 22 against anvil 124.

Referring to Figure 21, apparatus 146 is shown in operation in a closed position, with cutting edge 160 of punch 148 in contact with sheeting 22. As die 152 is raised toward punch 148, sheeting 22 is shear cut or die cut as cutting edge 160 on punch 148 contacts sheeting 22. If sheeting 22 is shear cut, the shape of punch 148 is cut into sheeting 22, while sequentially heating, compressing, and sealing the porous or open cell cut edges of the piece part 63 left in sheeting 22 between sealing flats 158 on seal ring 150 and die 152 immediately after being cut. Generally, the cut edges of the material to be discarded, i.e., the slug 153, are not sealed. Sheeting 22 is completely cut through. Sheeting 22 is preferably compressed to a height H of about 0.13 mm to about 0.25 mm, more preferably about 0.18 mm, between sealing flat 158 and die 152 where sheeting 22 has been shear cut, as shown in Figure 22.

Apparatus 146 can be used to simultaneously die cut and seal around a desired design periphery to produce a porous edged article in the sheeting. The cut edge of piece part 63 is generally sealed, and the cut edge of slug 153 is generally not sealed. Preferably, apparatus 146 may cut all the way through

release liner, as shown in Figure 21, so that the design periphery which has been die cut is releasably adhered to the release liner having the same shape as the design periphery, and discarding the slug of the punched hole.

The embodiments shown in Figures 15-21 are particularly useful in applications involving reflective sheeting containing glass beads, such as 3M Scotchlite brand High Intensity Grade reflective sheeting No. 790. Glass beads are abrasive and destructive to steel blades, such that steel blades often are chipped or abraded. It is preferred to use harder materials, such as carbide steel, for the cutting edges in these embodiments. The embodiments shown in Figures 15-21 use a shearing action to completely cut sheeting 22 rather than pinch cutting the sheeting. Sheeting 22 is pinched at the end of the shearing stroke. The embodiments shown in Figures 15-21 may be utilized for retroreflective sheeting, such as 3M Scotchlite brand High Intensity Grade sheeting No. 790 and 3M Scotchlite brand Diamond Grade sheeting No. 980, manufactured by Minnesota Mining and Manufacturing Company of St. Paul, Minnesota. Less force may be used with the embodiments of Figures 15-21 since the shear cutting breaks or interrupts the two surfaces of sheeting 22 at different times.

Sealing flats in the embodiments shown in Figures 1-12 and Figures 15-21 having width dimensions greater than about 1.2 mm tend to create excessive waste sheeting with respect to reflective performance. In addition, sealing flat width dimensions greater than about 1.2 mm tend to create undesirable surface deformations of sheeting 22. This may result in handling, packaging and optical performance degradation. Sealing flats having width dimensions less than about 0.25 mm tend to exhibit inadequate sealing and are more conducive to breakdown of the

sheeting at the region which was cut. The range of optimum widths for sealing flats in the embodiments shown in Figures 1-12 and Figures 15-21 is additionally advantageous with respect to minimizing damage to closely spaced reflective elements within sheeting 22. The physical integrity of these elements is essential to proper optical performance of the sheeting. In addition, the width of the sealing leg of the sealed edge, as determined by the width of the sealing flats on the tools in the embodiments in Figures 1-12 and Figures 15-21, relates to the amount of whiteness in sheeting 22. The amount of desired whiteness, as distinguished from retroreflective brightness, varies according to each intended use. The wider the sealing flats, the more whiteness and the less the brightness in sheeting 22.

A correlation between heat and the time and pressure used to complete a cut has been indicated. Cutting conditions of sheeting 22 will vary depending on the material comprising sheeting 22. For example, one combination of heat, time and pressure for pinch cutting and sealing a polycarbonate based material, such as 3M Scotchlite brand Diamond Grade sheeting No. 980, preferably has temperatures varying in range between about 204°C (400°F) and about 250°C (482°F), most preferably 238°C (460°F), at a pressure of approximately 9 kilos per centimeter for approximately 0.2 seconds. Alternatively, for pinch cutting a urethane based product, such as 3M Scotchlite brand High Intensity Grade sheeting No. 790, temperatures may range between about 76°C (170°F) to about 94°C (200°F) at a pressure of approximately 10 to 12 kilos per centimeter for approximately 0.3 seconds. If the temperature is too low, edges will not seal adequately and properly. If the temperature is too high, sheeting 22 will stick to the die and the edges will peel or roll up. Pinch cutting requires more force than shear

cutting since the material in sheeting 22 is being forced in different directions while cutting and sealing at the same time. Shear cutting involves interrupting two surfaces sequentially, so less force is required. The above ranges are also applicable to shear cutting, except that less pressure is required.

Figure 22 is a cross section schematic view of a representative cut retroreflective sheeting 22 using the devices and methods shown in Figures 8 and 15-21. Referring to Figure 8, the cut and sealed edge of piece part 63 would be similar to edge 49c in Figure 22, and the cut edge of the scrim material would be similar to cut edge 49 shown in Figure 13. As shown in Figure 22, sheeting 22 comprises liner 56, adhesive layer 41, plastic resin layer 43, reflective layer 45, and air spaces 47 positioned between reflective layer 45 and plastic resin layer 43. Edge 49c is essentially a straight cut since sheeting 22 is shear cut in these embodiments. In sealed area 53c, retroreflective layer 45 is welded or heat sealed to resin layer 43. Sheeting 22 is preferably compressed to a height H of about 0.13 mm to about 0.25 mm, more preferably about 0.18 mm. Air spaces 47 are eliminated from sealed area 53c as sheeting 22 is shear cut so that no moisture or particulates can enter remaining air spaces 47.

The preferred dimensions of the sealing flats or sealing surfaces, and the height between the sealing flats/sealing surfaces and the anvil are quite important to achieving successful articles of manufacture. In addition, acceptable cutting through some types of retroreflective material has been limited because of the material used in the blades, particularly when now combining a preferably simultaneous heating feature as a performance requirement of the blades.

The apparatus and methods used in the invention are also advantageous since the sealing of

the sheeting permanently eliminates the air spaces at the very edge of the porous sheeting. Less area of the sheeting is wasted as compared to the ultrasonic weld method which wastes significant amounts of the sheeting material. Since the edges of the porous or open cell sheeting are sealed, no liquid sealer is needed, which is advantageous environmentally. Also, using the novel apparatus and methods of the invention cuts and seals the sheeting material more quickly than the application of liquid sealer or using the ultrasonic cross web method. Further, previously laminated sheeting may be sealed simultaneously or substantially simultaneously with the cutting action.

CLAIMS:

1. An apparatus for simultaneous cutting and sealing of an edge of a porous edged sheeting, characterized in that the apparatus comprises:

a) a cutting blade for cutting the sheeting, the cutting blade having a cutting edge and a mounting plate;

b) at least one sealing flat adjacent to and integral with the cutting blade for compressing and sealing the cut sheeting;

c) heating means arranged in thermal transfer relation to the sealing flat for heating the sealing flat to aid in the sealing of the sheeting; and

d) an anvil for positioning the sheeting proximate the cutting blade and the at least one sealing flat, so that the cut edge of the sheeting is simultaneously cut and sealed to close the exposed pores to prevent contamination of the sheeting.

2. The apparatus of claim 1 further characterized in at least one of the following:

a) the heating means heats the cutting blade; or

b) the heating means ranges in temperature between about 76°C and about 250°C.

3. The apparatus of claim 1 further characterized in at least one of the following:

a) the apparatus is configured to cut completely through a full thickness of the sheeting; or

b) the apparatus further comprises stop means adjacent the anvil and the cutting blade for permitting only partial cutting through a thickness of the sheeting; or

c) the distance between the anvil means and the at least one sealing flat ranges between about 0.13

millimeters and about 0.25 millimeters as the sheeting is sealed; or

d) the cutting blade and the sealing flat rotate about an axle; or

e) the anvil rotates about an axle.

4. The apparatus of claim 1 characterized in that the apparatus further comprises a stripper plate to prevent the sheeting from sticking to the cutting blade.

5. The apparatus of claim 4 further characterized in that the stripper plate is resiliently connected to the cutting blade.

6. An apparatus for cutting and sealing a porous edged sheeting, characterized in that the apparatus comprises:

a) a first cutting blade for shearing the sheeting, the first cutting blade having a first cutting edge;

b) a second cutting blade for shearing the sheeting, the second cutting blade having a second cutting edge which shears the sheeting as the first cutting edge contacts the second cutting edge;

c) a first anvil adjacent the second cutting blade for positioning of the sheeting against the first cutting blade;

d) at least one sealing flat adjacent to and integral with at least one of the first and second cutting blades and the first anvil for sealing a cut edge of the sheeting, the at least one sealing means of the first cutting blade and the first anvil having a width between about 0.254 millimeters and about 0.76 millimeters; and

e) heating means arranged in thermal transfer relation to the at least one sealing flat for

heating the at least one sealing flat, so that the cut edge of the sheeting is cut and immediately sealed to close the exposed pores of the sheeting and to prevent contamination of the sheeting.

7. The apparatus of claim 6 further characterized in that the heating means further heats the first cutting blade and the first anvil means.

8. The apparatus of claim 6 further characterized in that the apparatus further comprises second anvil means adjacent the first cutting blade for positioning the sheeting against the second cutting blade, and further comprising at least one sealing flat adjacent to and integral with the second anvil means.

9. The apparatus of claim 12 characterized in at least one of the following:

a) the sheeting is completely cut through a full thickness of the sheeting; or

b) the compression height of the sheeting between the at least one sealing flat on the first cutting blade and the at least one sealing flat on the first anvil means is about 0.13 millimeters to 0.25 millimeters, and the compression height of the sheeting between the at least one sealing flat on the second cutting blade and the at least one sealing flat on the second anvil means is about 0.13 millimeters to 0.25 millimeters; or

c) the first cutting blade and the first anvil means rotate about a first axle, and the second cutting blade and the second anvil means rotate about a second axle; or

d) the heating means ranges in temperature between about 76°C and about 250°C; or

e) the first and second cutting blades comprise carbide steel.

10. A method for simultaneous pinch cutting, die cutting, or kiss cutting and sealing of a porous edged sheeting, characterized in that said method comprises the steps of:

a) providing an anvil and an opposing cutting and sealing tool;

b) heating the cutting and sealing tool;

c) positioning a porous edged sheeting having a thickness on the anvil;

d) moving the anvil and the cutting and sealing tool relative to each other until the sheeting comes in contact with the cutting and sealing tool;

e) cutting the sheeting by pressing the cutting and sealing tool into the sheeting to a predetermined depth; and

f) simultaneously sealing and compressing the sheeting between the cutting and sealing tool and the anvil, thereby closing the exposed pores of the sheeting and preventing contamination of the sheeting.

11. The method of claim 10 characterized in at least one of the following:

a) the method further comprises rotating the cutting and sealing tool and the anvil to cut the porous edged sheeting; or

b) the apparatus is configured to cut completely through a full thickness of the porous edged sheeting; or

c) the method further comprises providing stop means for permitting only partial cutting of a thickness of the porous edged sheeting.

12. A method for shear cutting and sealing a porous edged sheeting, characterized in that the method comprises the steps of:

a) providing a first assembly having a first cutting surface, a first anvil, and at least one

sealing surface, the first anvil being adjacent the first cutting surface, the first cutting surface having a first cutting edge;

b) providing a second assembly having a second cutting surface, the second assembly opposing the first assembly;

c) heating the first assembly;

d) positioning a porous edged sheeting on the second assembly;

e) moving the first cutting edge by the second cutting edge to completely shear and cut the sheeting; and

f) sealing and compressing the sheeting substantially simultaneously between the first assembly and the second assembly.

13. The method of claim 12 further characterized in at least one of the following:

a) the method further comprises providing a second assembly having at least one sealing surface and a second anvil, the second anvil being adjacent the second cutting surface, the second cutting surface having a second cutting edge; or

b) the method further comprises rotating the first assembly and the second assembly so as to cut the porous edged sheeting.

Fig. 1

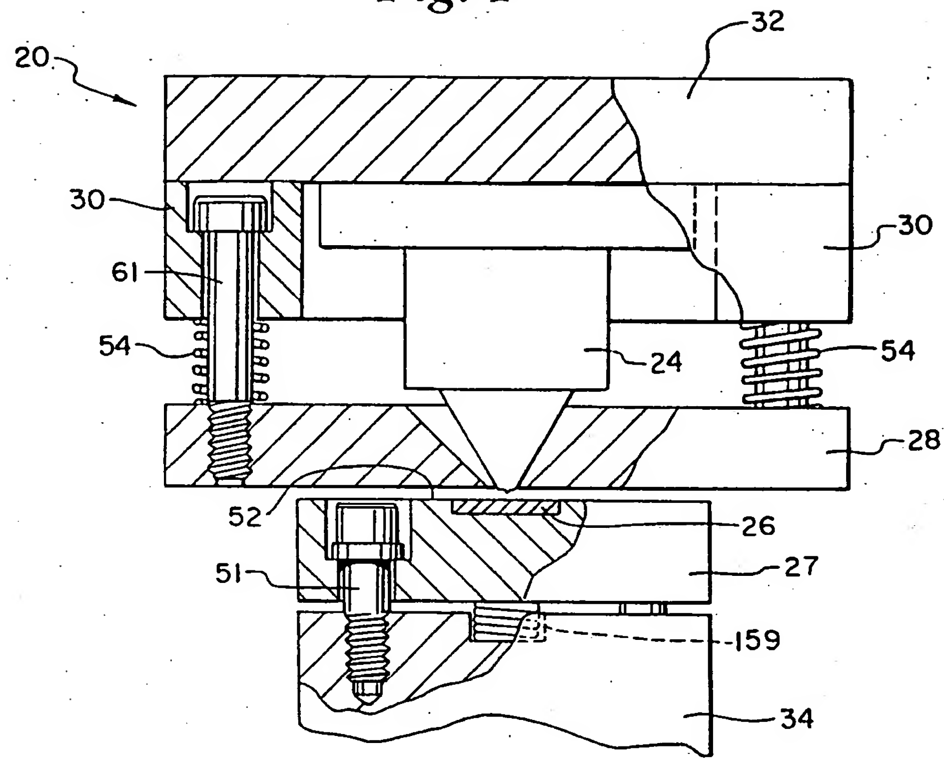

Fig. 2

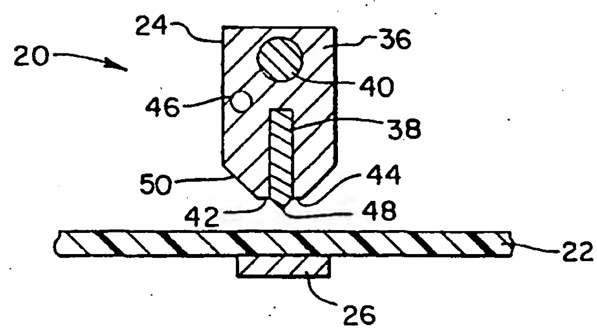

Fig. 3

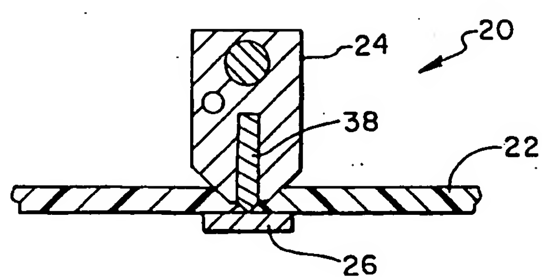

Fig. 4

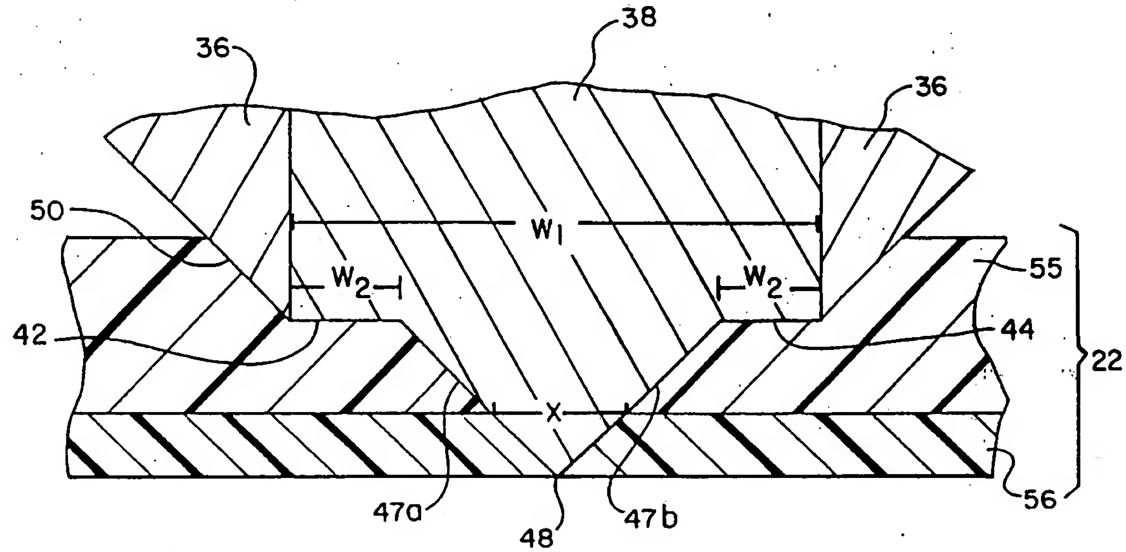
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Fig. 5

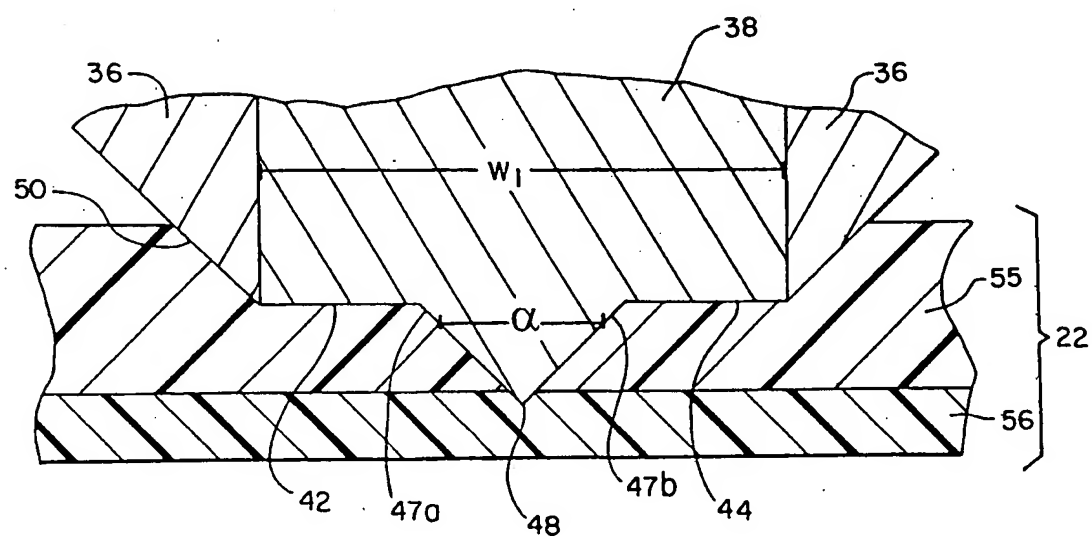
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Fig. 6

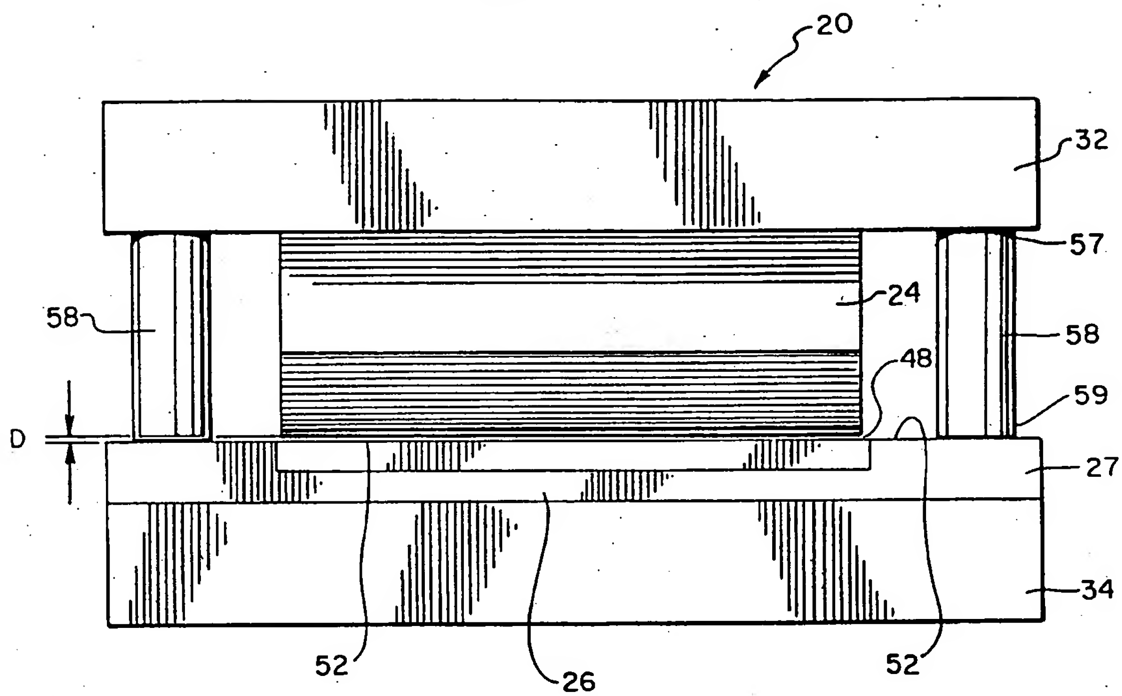

Fig. 7

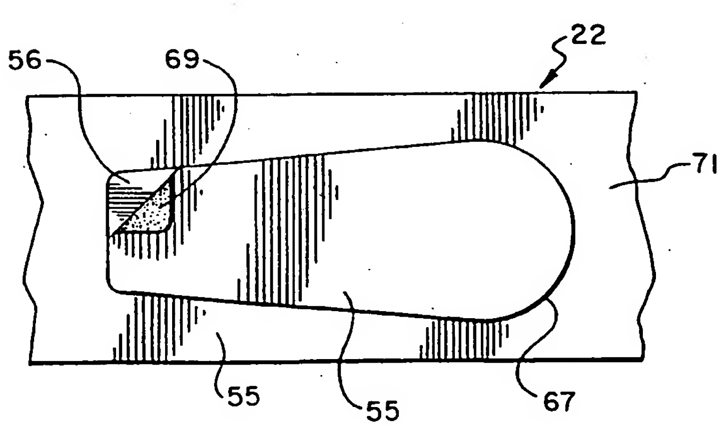

Fig. 8

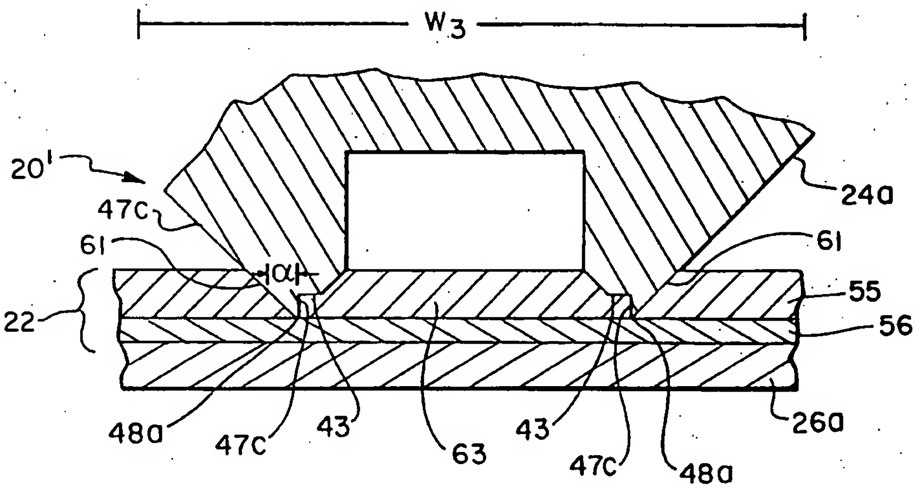

Fig. 9

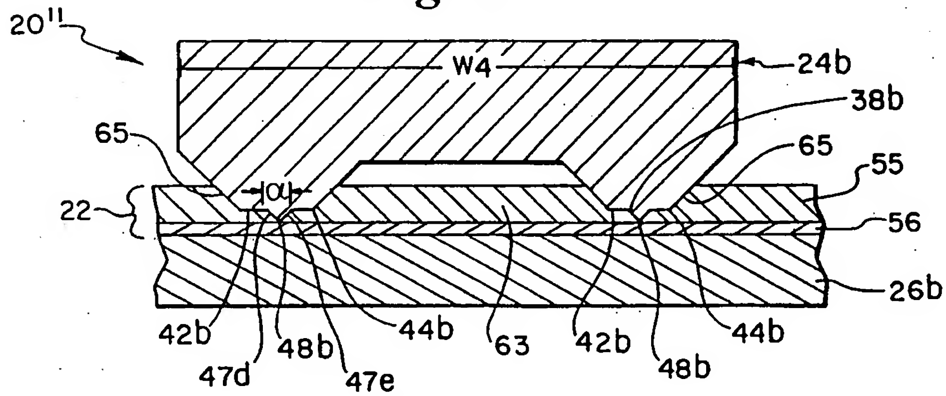

Fig. 10

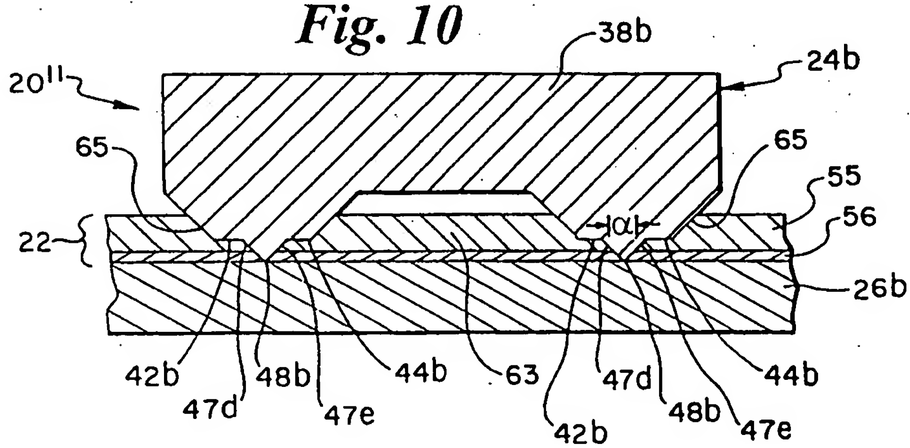

Fig. 11

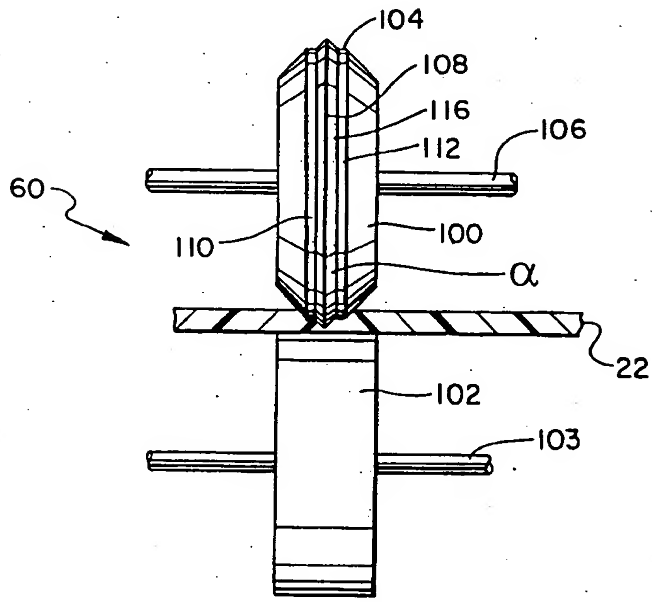
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Fig. 12

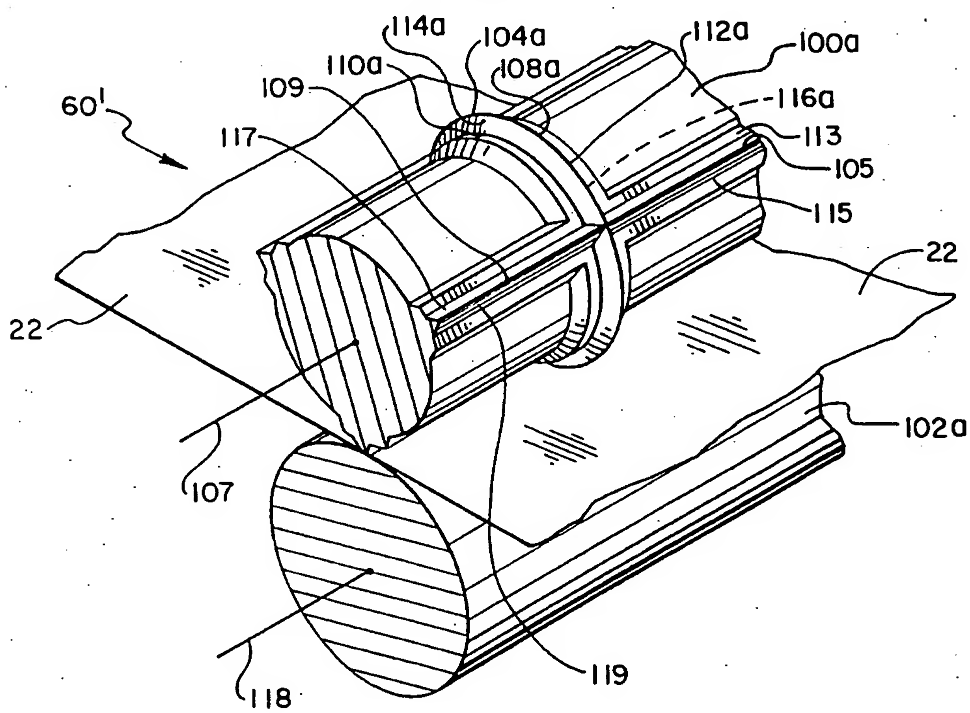
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Fig. 13

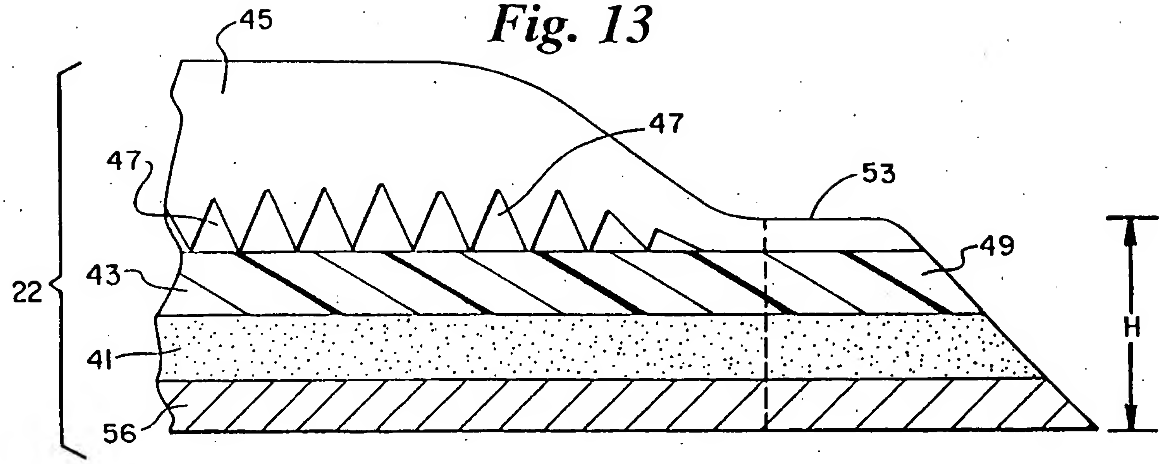
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Fig. 14

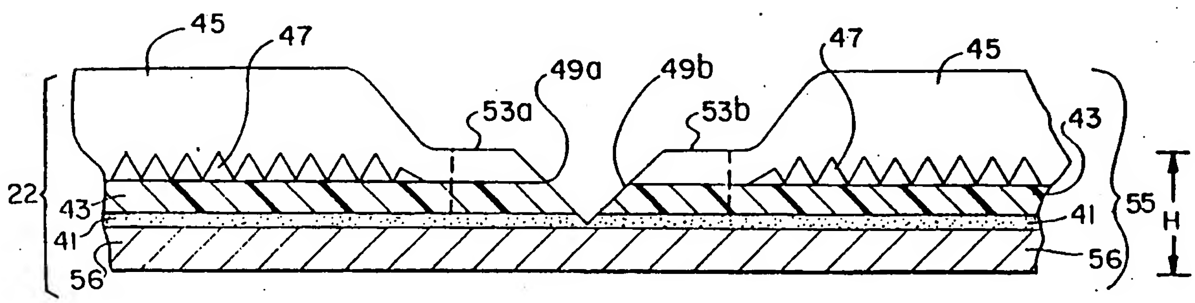
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Fig. 15

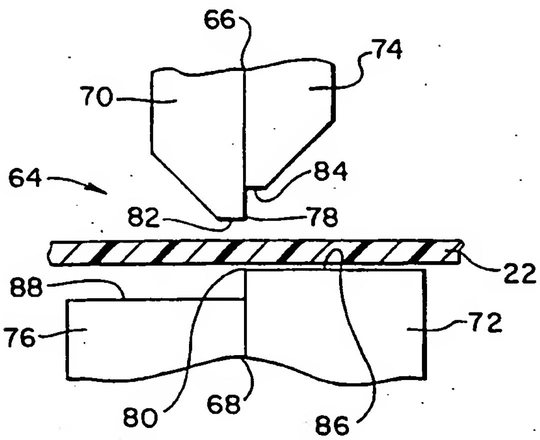


Fig. 17

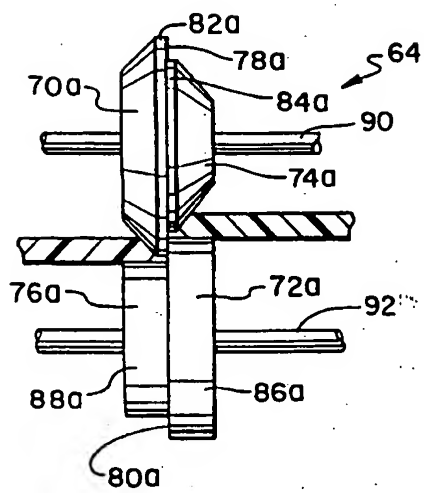


Fig. 16

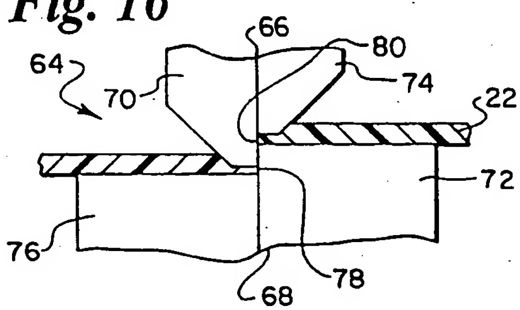


Fig. 18

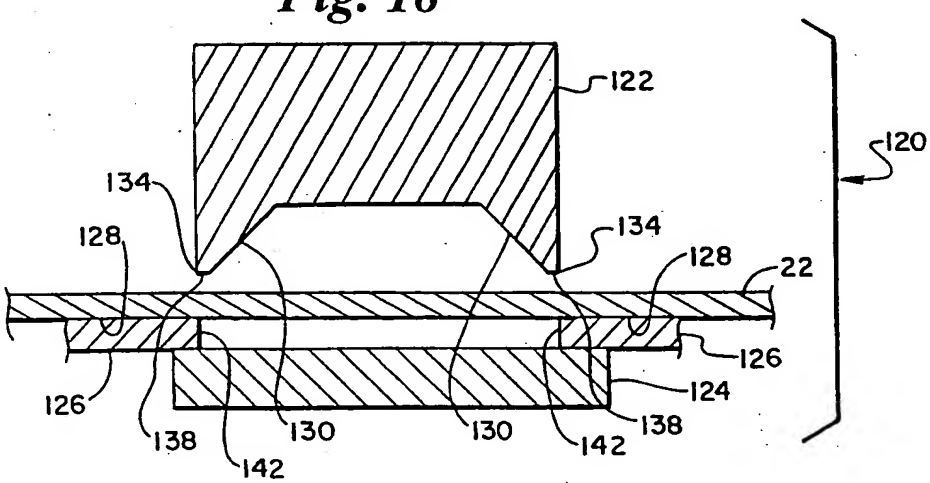


Fig. 19

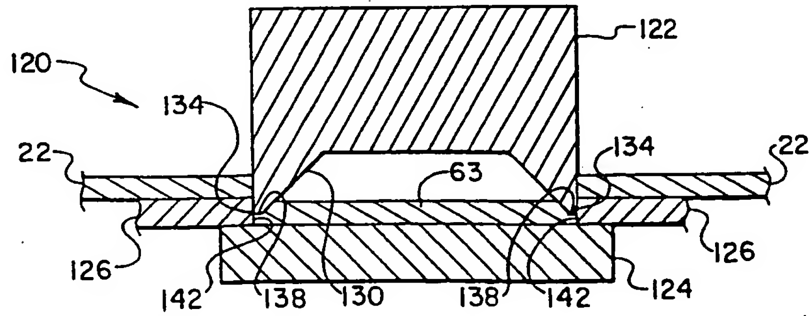


Fig. 20

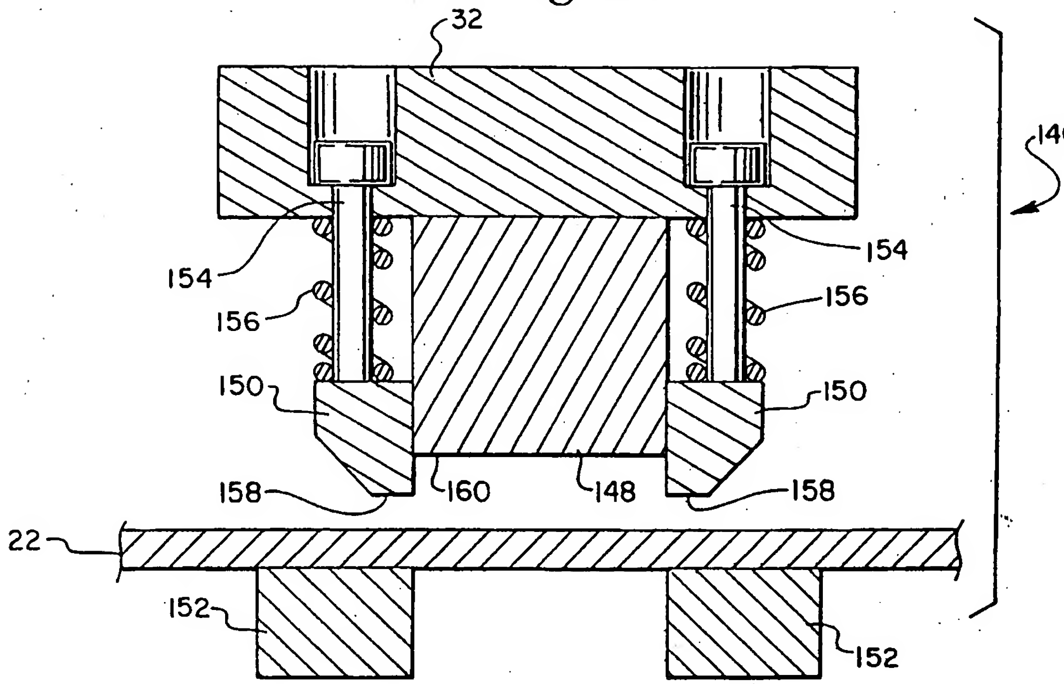


Fig. 21

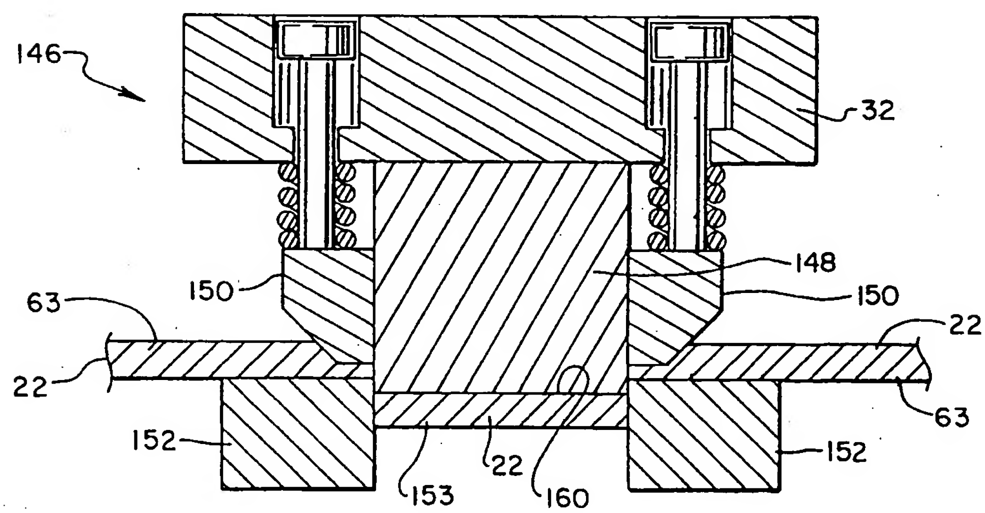
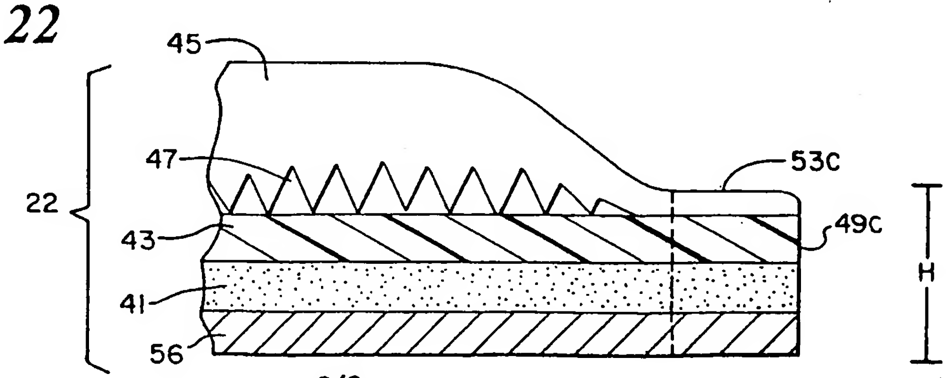


Fig. 22



INTERNATIONAL SEARCH REPORT

Inte ..onal Application No
PCT/US 95/02649

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B29C67/00 B29C65/74

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B29C B31F B31B B26D B21D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP-A-0 535 998 (CAIRWAY LTD) 7 April 1993 see column 1, paragraph 2 see column 4, line 47 - column 5, line 6; figures 2,4 ---	1-7,9-12
X	DE-A-38 13 104 (PAUL KIEFEL HOCHFREQUENZ-ANLAGEN GMBH) 9 November 1989 see column 2, line 37 - line 41; figures ---	1-5,10, 11
X	US-A-4 384 908 (KLEIST WILLIAM E) 24 May 1983 see abstract; figures ---	1-5,10, 11
X	EP-A-0 086 869 (RISSEN GMBH MASCHF ;DELTAPLASTIC GMBH & CO KG (DE)) 31 August 1983 see page 17, paragraph 2 see claims 1,3,4; figures 8,10 ---	1-7,9-13
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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 August 1995	22.08.95

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/02649

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US-A-5 110 399 (Y. YOSHIDA) 5 May 1992 cited in the application see figure 4 ---	4,5
A	US-A-2 633 441 (G.A. BUTTRESS) 31 March 1953 see figure 5 ---	6
A	AU-D-6 382 580 (R.F. DYMKE) 14 May 1981 see claim 1; figures ---	
A	FR-A-2 221 256 (IMPRESSION CARTONNAGE) 11 October 1974 see figure ---	
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1

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US-A-2552353	08-05-51	NONE		
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